



Mars Ascent System for a Potential Mars Sample Return Campaign

Ashley Karp

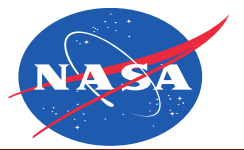
Jet Propulsion Laboratory,
California Institute of Technology
Sept. 2021

The decision to implement Mars Sample Return will not be finalized until NASA's completion of the National Environmental Policy Act (NEPA) process. This document is being made available for information purposes only.

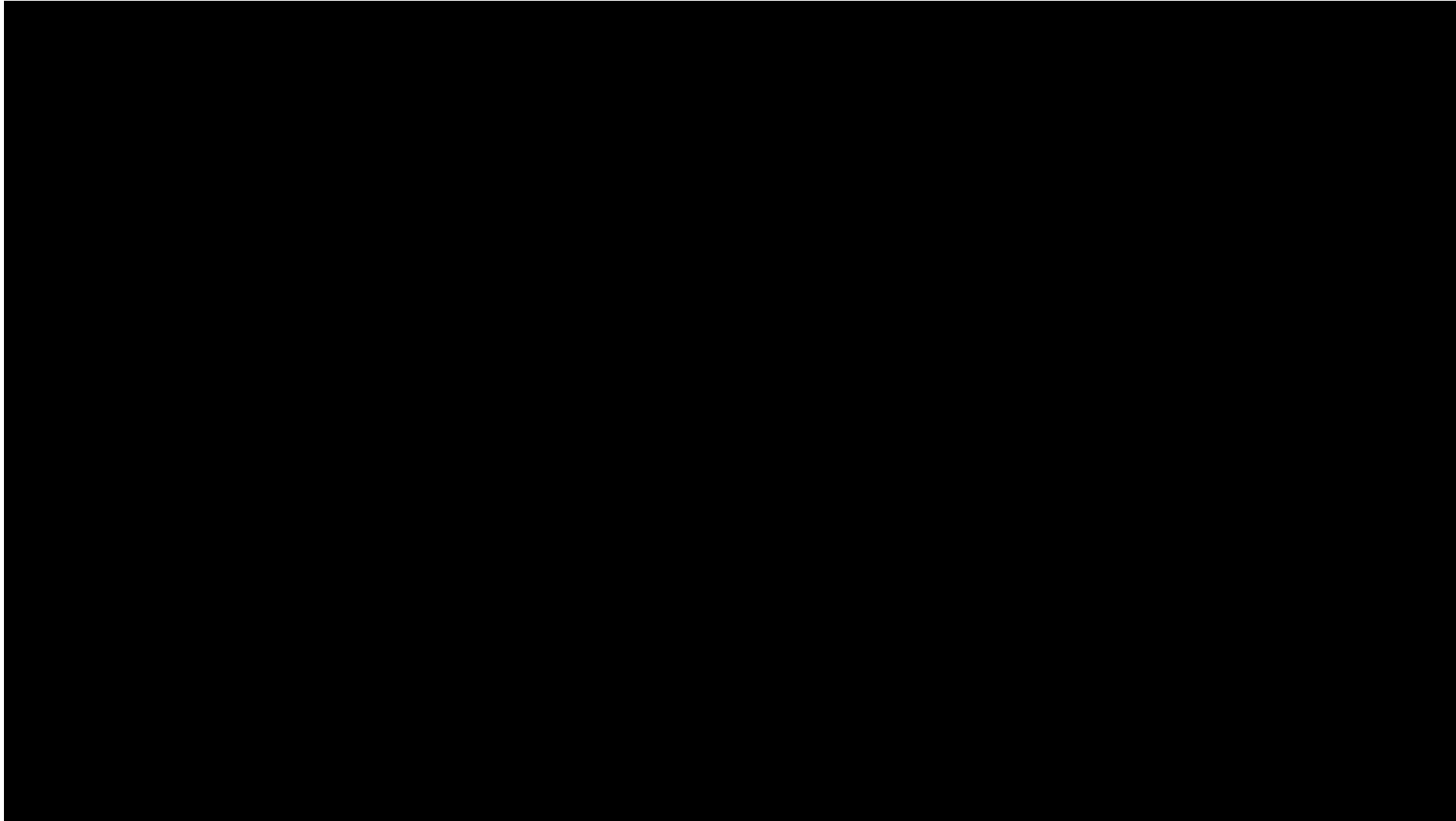
Some materials courtesy of Shawn Goodman and Marshall Spaceflight Center



Potential MSR Campaign Video

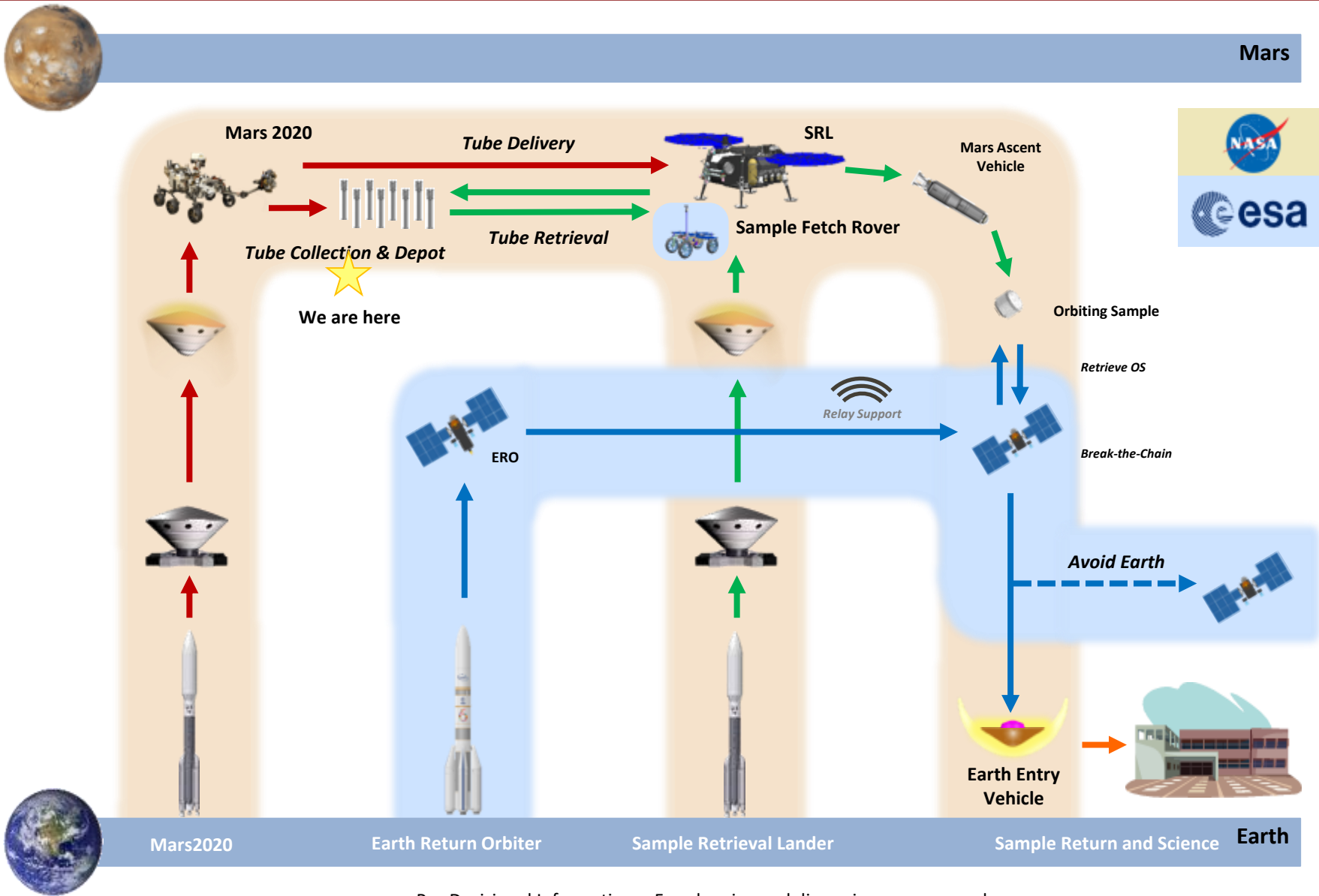


Mars Sample Return Program



Pre-Decisional Information -- For planning and discussion purposes only.

Mars Sample Return Architecture Concept Overview

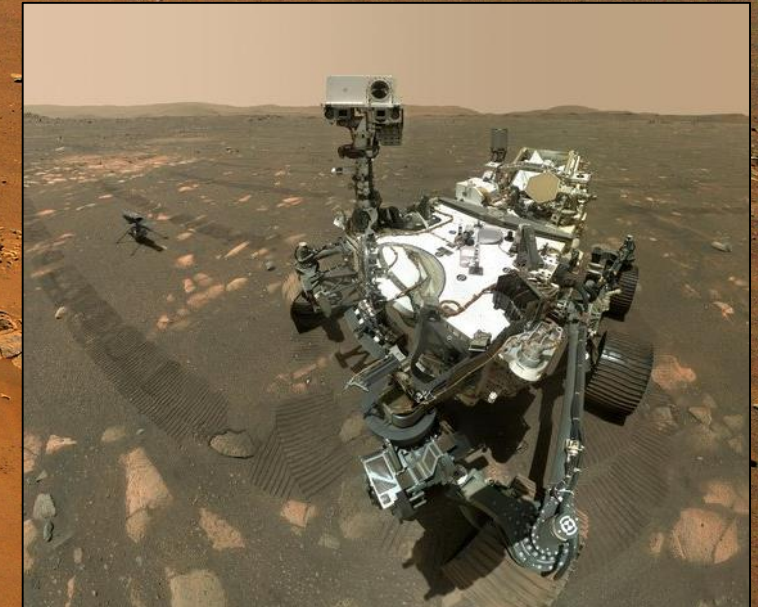
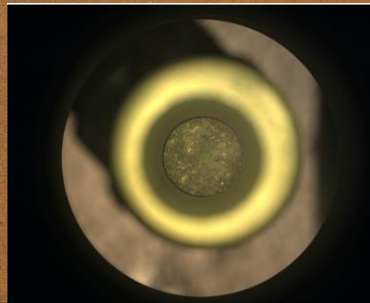


Perseverance – Gathering Samples for Possible Return



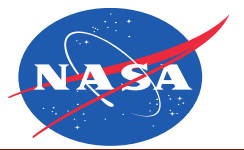
Mars Sample Return Program

- Launched: Cape Canaveral, FL on 30 July 2020
- Landed: Jezero Crater on 18 Feb 2021 (see left)
 - Landed 1.7 km southwest of the target location
- The Mars 2020/Perseverance rover is designed to better understand the geology of Mars and seek signs of ancient life. It will collect and cache samples of Martian rock and regolith
 - First two samples confirmed in September 2021 (below)

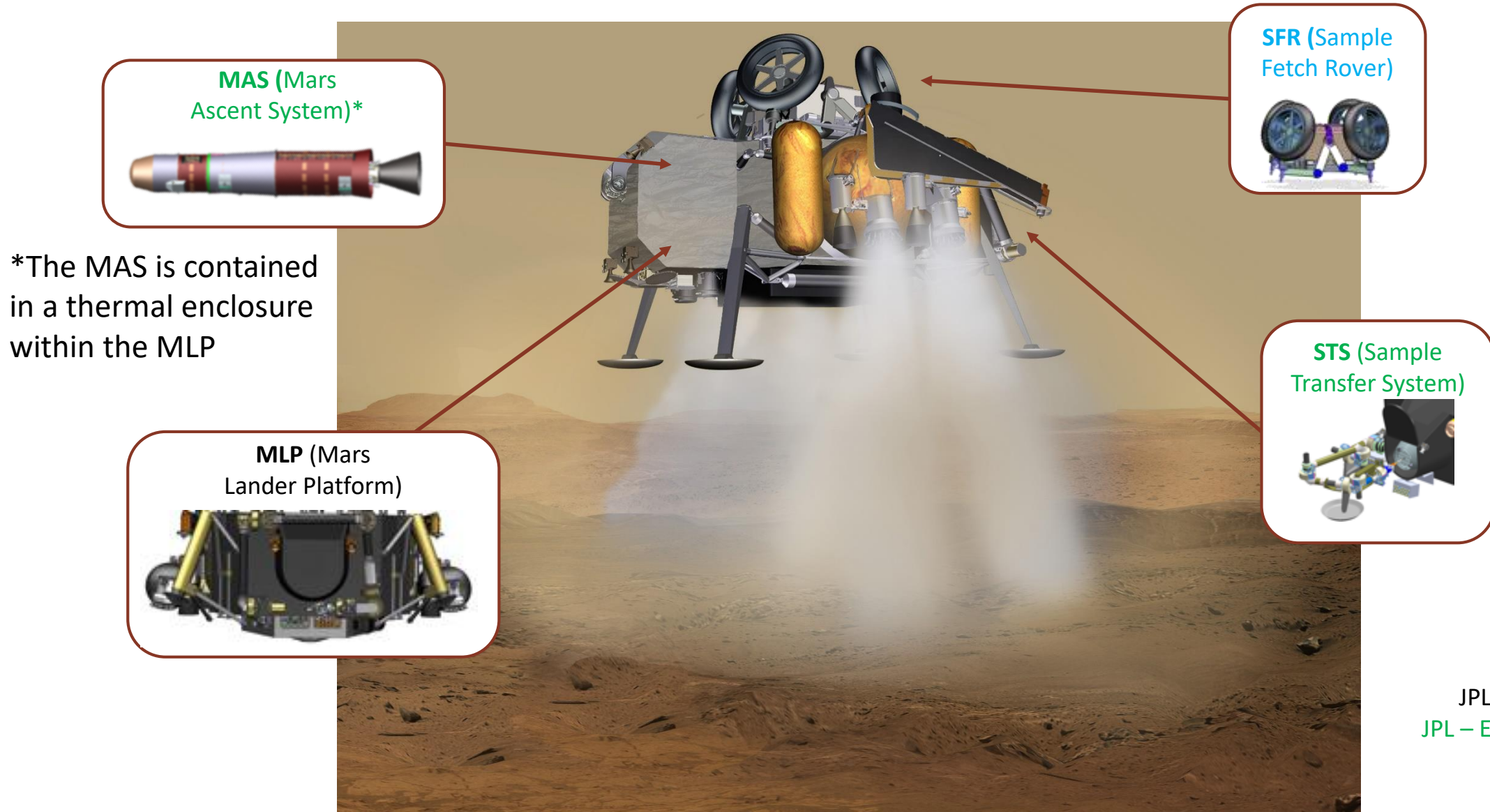


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Sample Retrieval Lander (SRL) – a potential next step

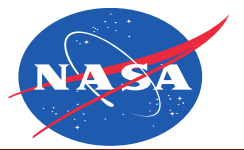


Mars Sample Return Program



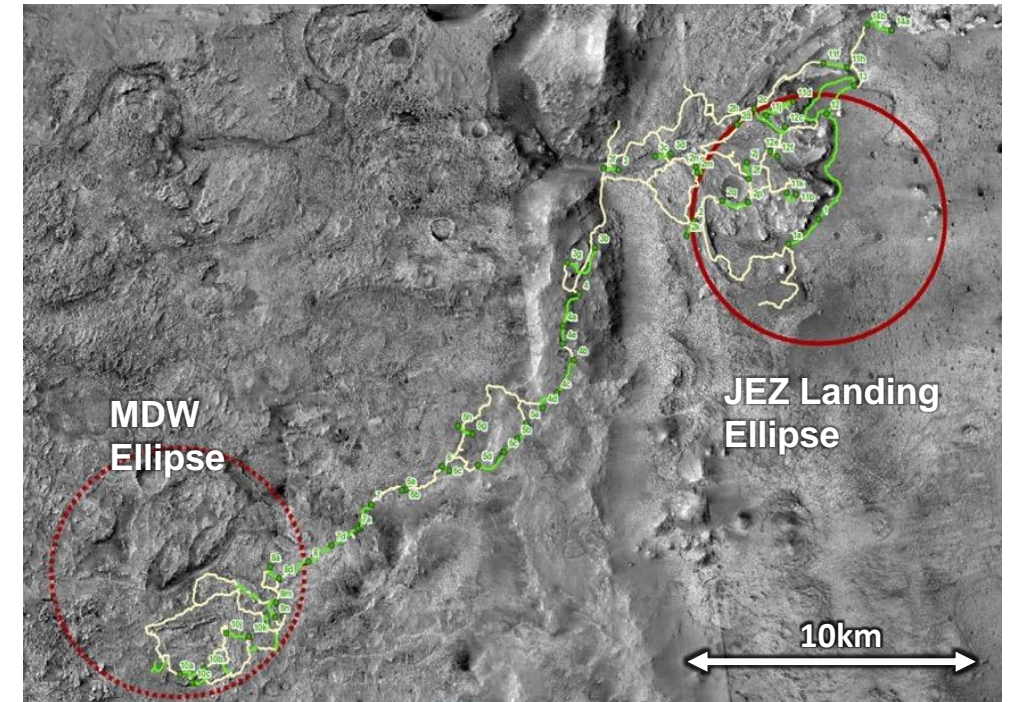
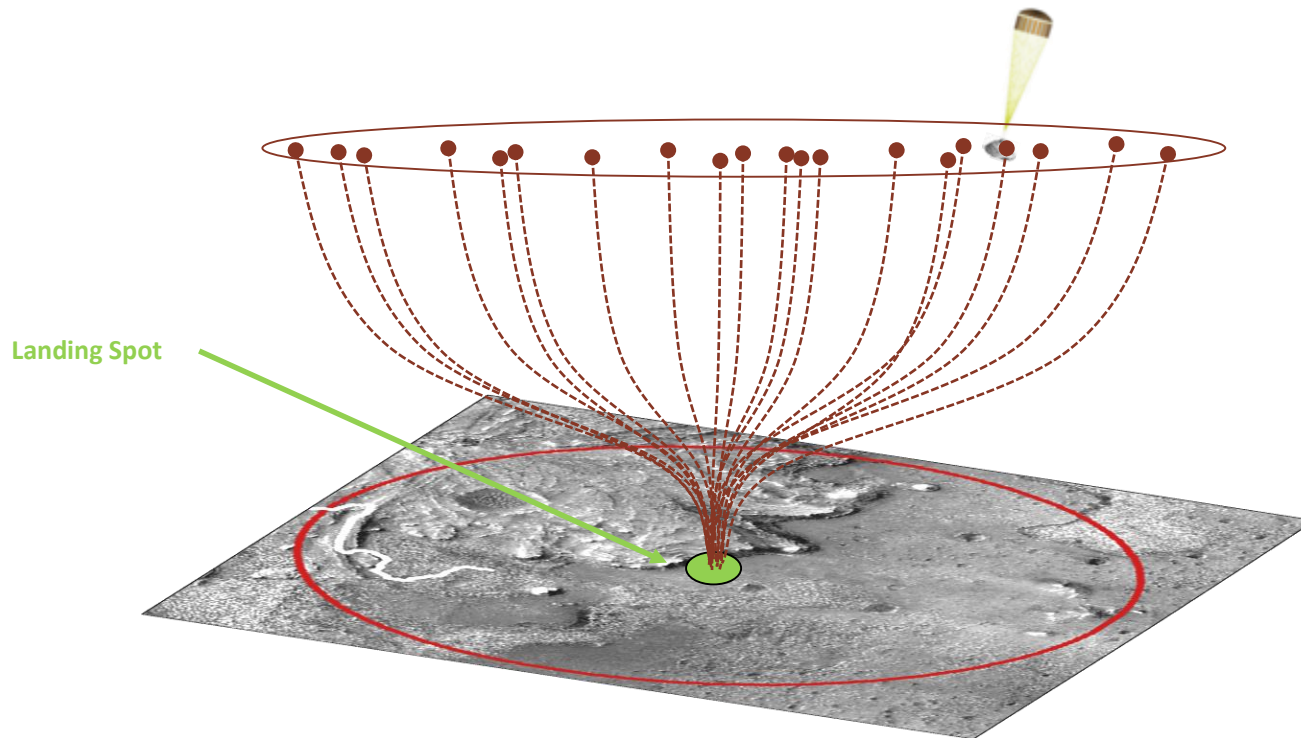
Organization
JPL – Flight System
JPL – Engineering Payload
MSFC
ESA

SRL Entry Descent and Landing (EDL)

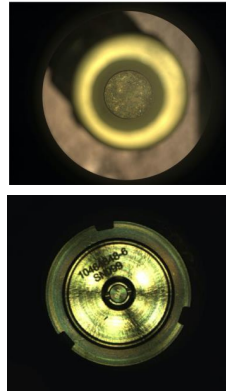
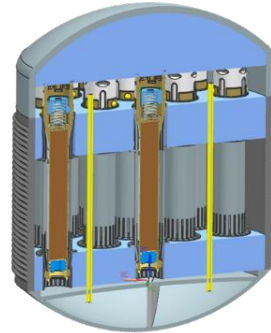


Mars Sample Return Program

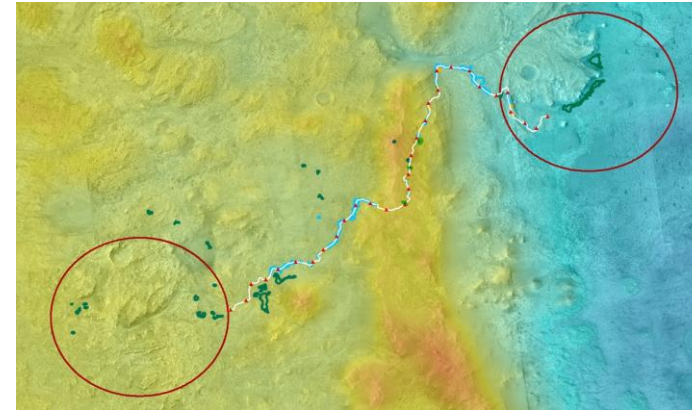
- Extended divert: SRL lander could land at a specific location on the Mars surface.
 - SRL will carry enough propellant to fly out the backshell separation ellipse (8 x 8 km) and land at a specific spot ($\sim \pm 20\text{m}$ accuracy)



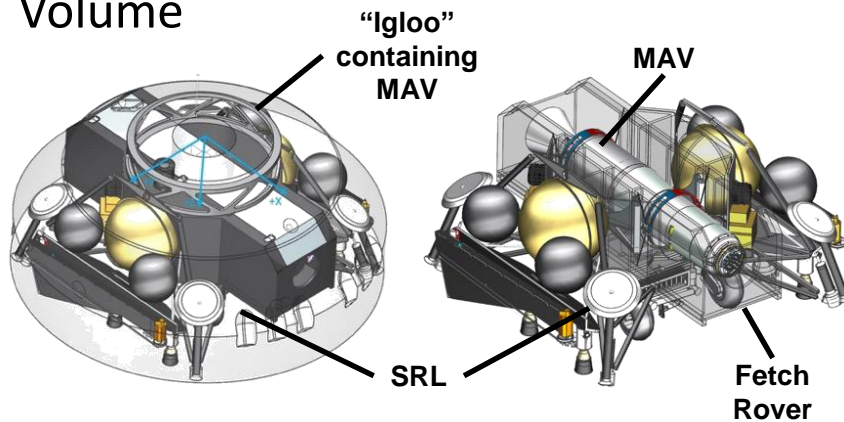
Payload mass



Mars Environment



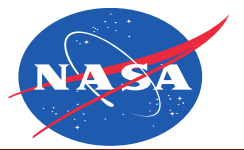
Volume



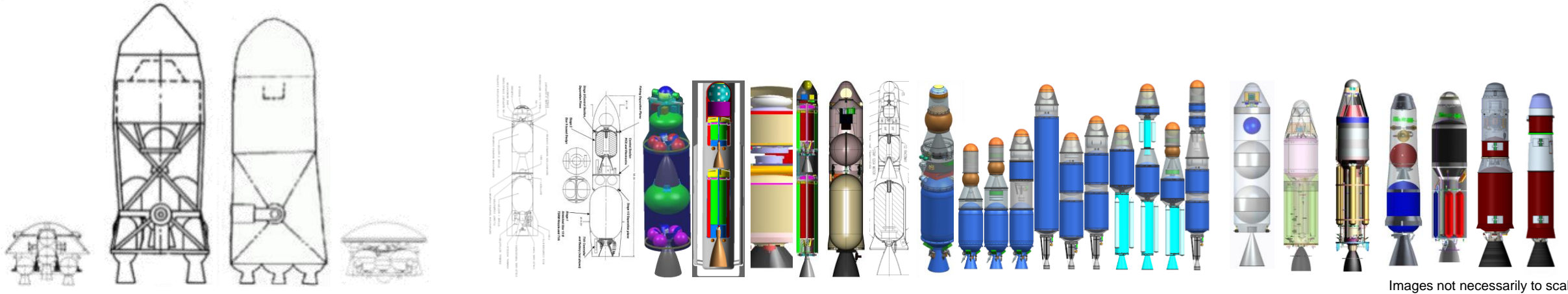
Allowable orbit dispersions



Mars Ascent System Propulsion Concept History



Mars Sample Return Program



- Initial assessments considered:
 - Hybrid propulsion system with liquid injection TVC – low GLOM, high performance in Martian environment (low TRL)
 - Testing of a full scale flight-like system completed at -20 C including restart and LITVC. Nozzle erosion for long duration burns was an issue.
 - Solid propulsion system – energy management mitigates orbital dispersion (high TRL for temperatures \geq -40 C)
 - Liquid second stage – challenges meeting power, volume and mass constraints
- Solid Propulsion Concept Enabled by:
 - Selection of Jezero Crater as landing site and Environmental constraints $>$ -40 C
 - Surface operations timeframe for SRL
- Decision to move to unguided 2nd stage made to reduce mass across the SRL
 - Larger orbital dispersions

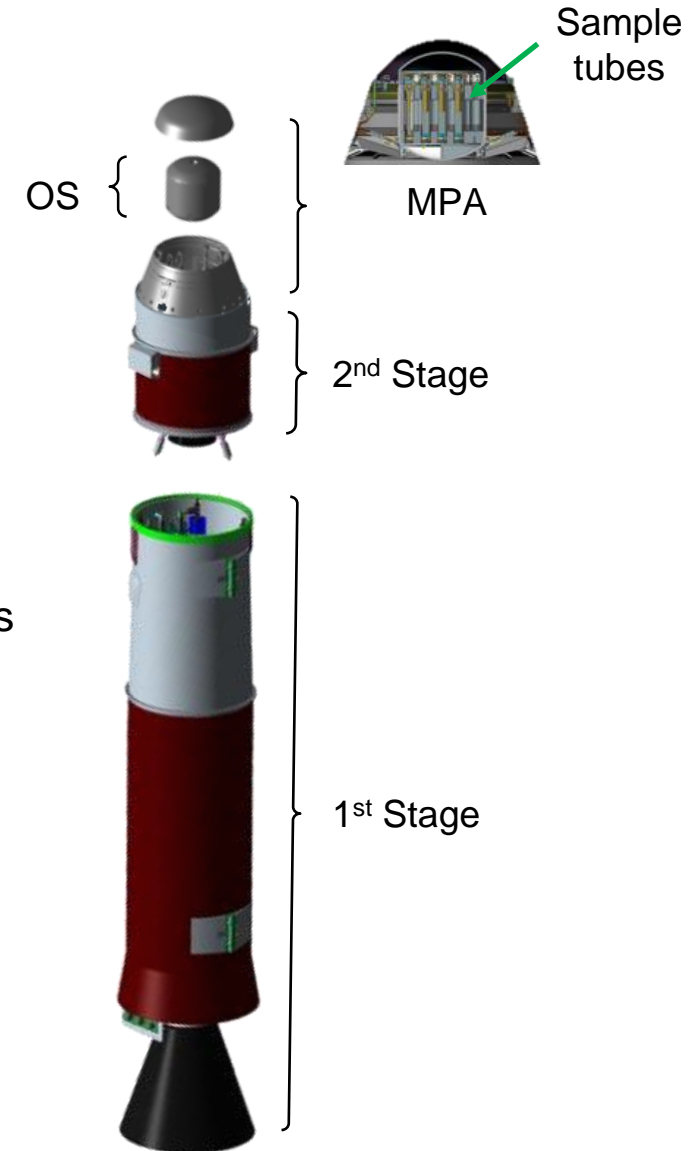
Mars Ascent System (MAS) Physical Architecture



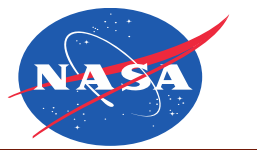
Mars Sample Return Program

Mars Ascent System (MAS) consists of:

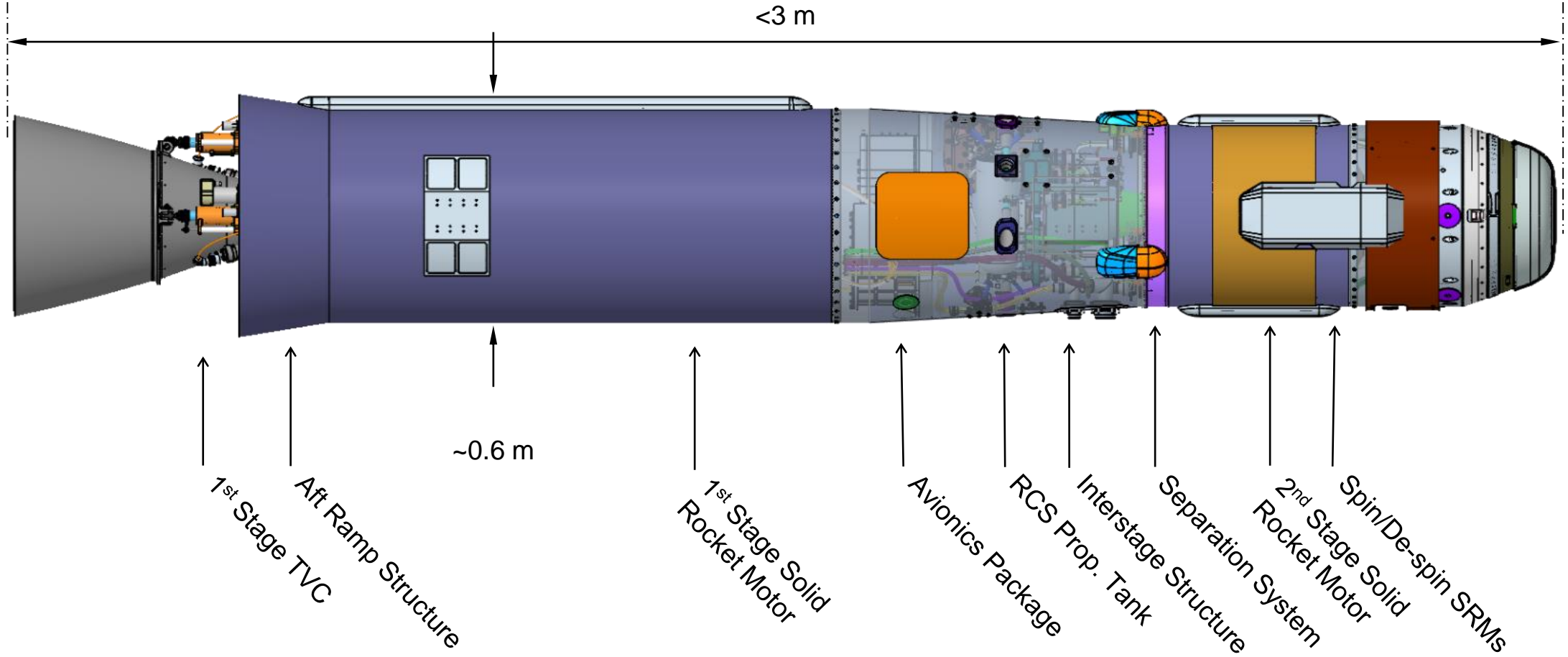
- Mars Ascent Vehicle (MAV)
 - To be delivered by Marshall Spaceflight Center (MSFC)
 - Two-stage solid motor vehicle
 - CTPB-based propellant
 - Thrust Vector Controlled 1st stage: Electrical-mechanical TVC with supersonic splitline nozzle
 - Spin Stabilized 2nd stage: 2x Spin Motors and 2x De-spin motors on 2nd stage
 - Spin up to ~200 RPM and spin down to <40 RPM
 - Monopropellant Reaction Control System (RCS) in the interstage: 6 x 5 N thrusters
- MAS Payload Assembly (MPA) and Orbiting Sample (OS)
 - Secure as many as 30 sample tubes
 - Enable sterile sample transfer in the CCRS/ERO
 - Secure the samples for earth impact



Mars Ascent System (MAS) Physical Architecture



Mars Sample Return Program



Pre-Decisional Information -- For planning and discussion purposes only.

MAS Important Parameters



Parameter	Value
Gross Lift Off Mass	450 kg
Payload (30 sample tubes)	16 kg*
Nominal Orbit	380 x 380 km
Nominal Inclination	27 deg
1 st Stage Motor Avg. Thrust	7.5 kN (boost-sustain)
2 nd Stage Motor Avg. Thrust	5.4 kN (spinning at 200 RPM)
RCS Propellant	Hydrazine
1 st Stage TVC Type	EM Actuator, supersonic splitline
Non-Operational Allowable Flight Temperature	-40°C to +40°C
Operational Allowable Flight Temperature	-25°C to +55°C
RCS Allowable Flight Temperature	+14°C to +40°C

*Value **includes** 1.83 kg nose cone that is ejected prior to 2nd stage burn.

Solid Rocket Motors for use at Mars

- Two previous missions used CTPB-based propellant at Mars. However, only for EDL, not for an extended surface mission.
 - Mars Exploration Rovers: Transvers Impulse Rocket System (Star 3)
 - Pathfinder: Rocket Assisted Deceleration (Star 5D)



TIRS motor

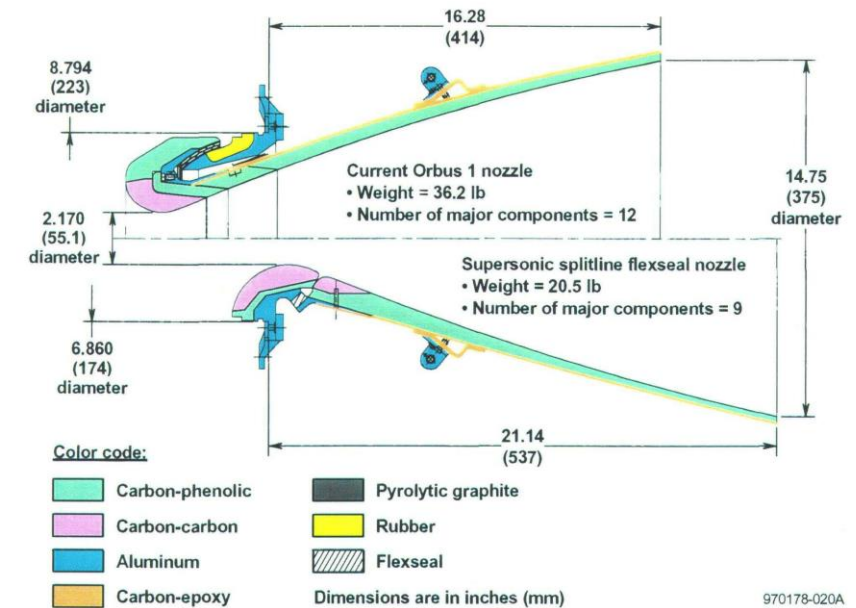


RAD motors

Images from the Propulsion Products Catalog.

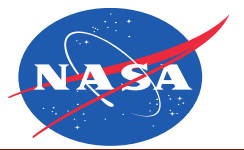
Supersonic Splitline TVC (Trapped Ball)

- Gimbal in supersonic section
- Nozzle performance at low temperature



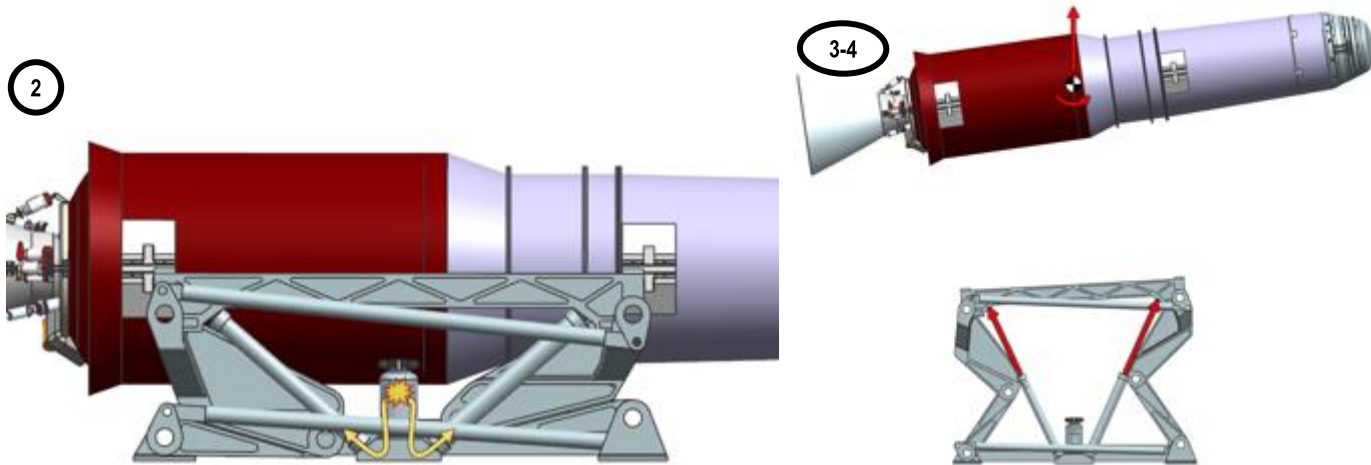
Ellis, R. et al. "Supersonic splitline (SSSL) flexseal nozzle technology evaluation program," 1997.

VECTOR – Deployment mechanism



Mars Sample Return Program

- Vertically Ejected, Controlled Tip-Off Rate (VECTOR) ejects the MAV away from the Lander in order to provide adequate separation distance from the Lander and terrain to minimize thrust interactions as well as improve flight time to on-trajectory (rolls into desired trajectory)
- ConOps (Mechanical)
 1. Release MAV Launch/CEDL Constraints; Open MAV Bay Door
 2. Fire Gas Generator (GG) which pressurizes the VECTOR pistons
 3. Pistons vertically eject the the MAV
 4. MAV ejection trajectory (translations and rotations) are controlled by the VECTOR mechanism until MAV/Lander separation occurs, at which point the MAV is in a free-flight condition with desired states

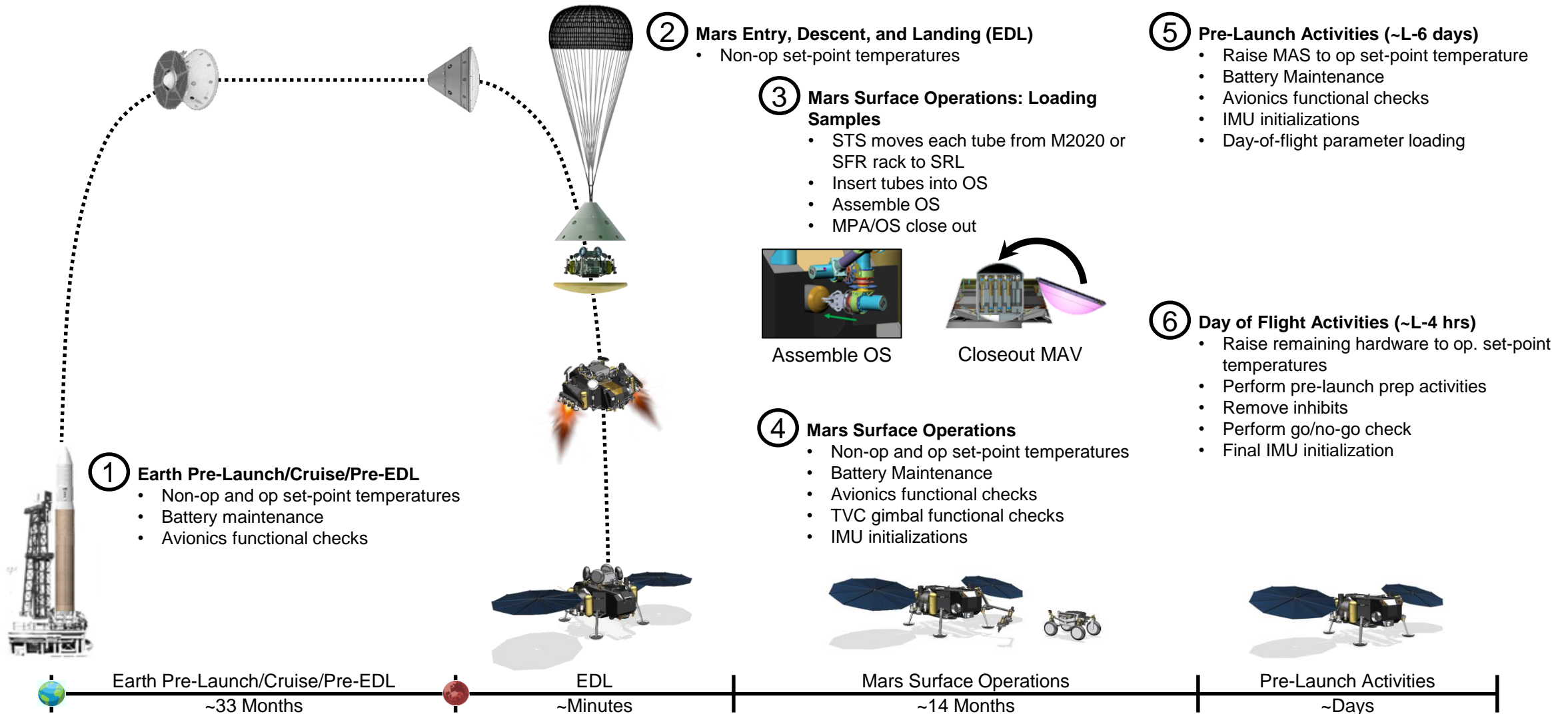


Inspiration came from the F-22's LAU-142/A and the F-35 LAU-147/A AMRAAM launch system which has similar functionality

MAS Stowed Mission Operations Overview

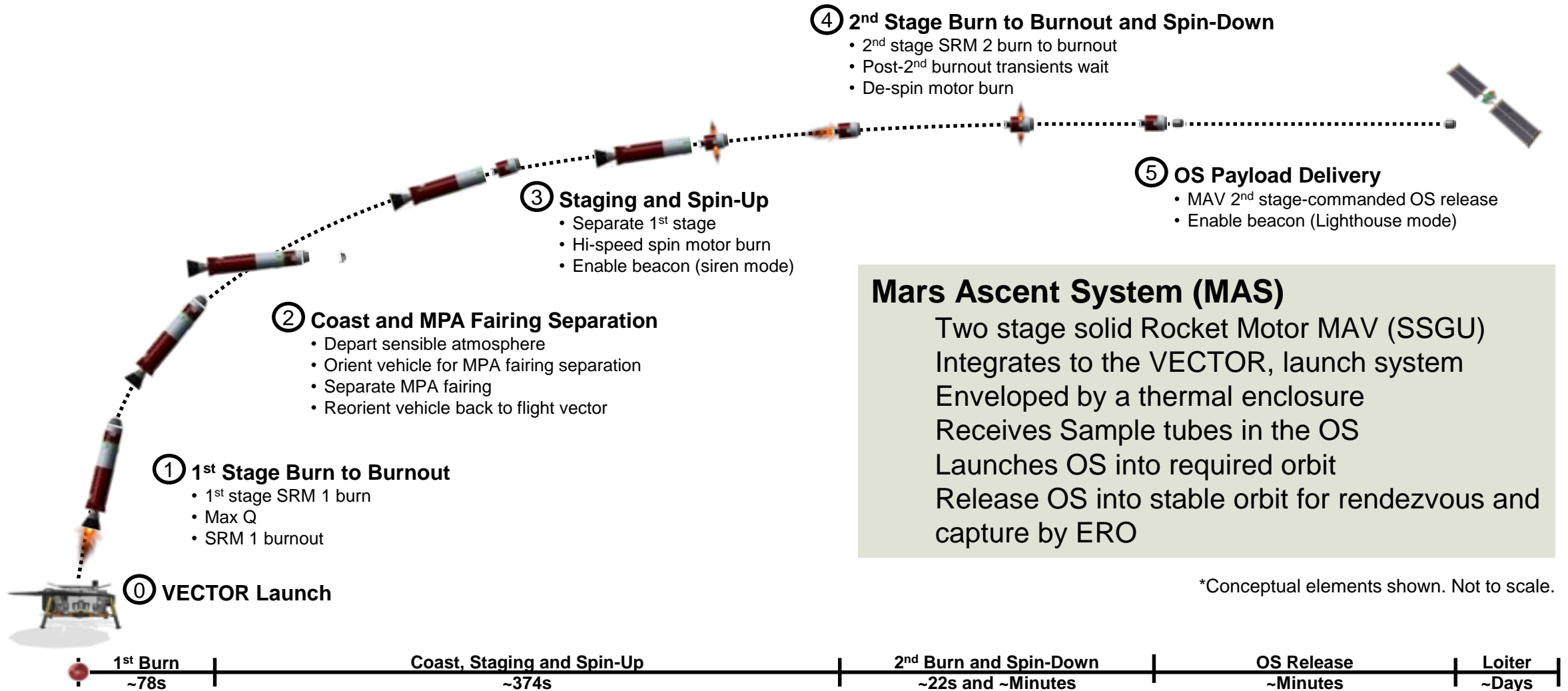


Mars Sample Return Program



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*Conceptual elements shown. Not to scale.

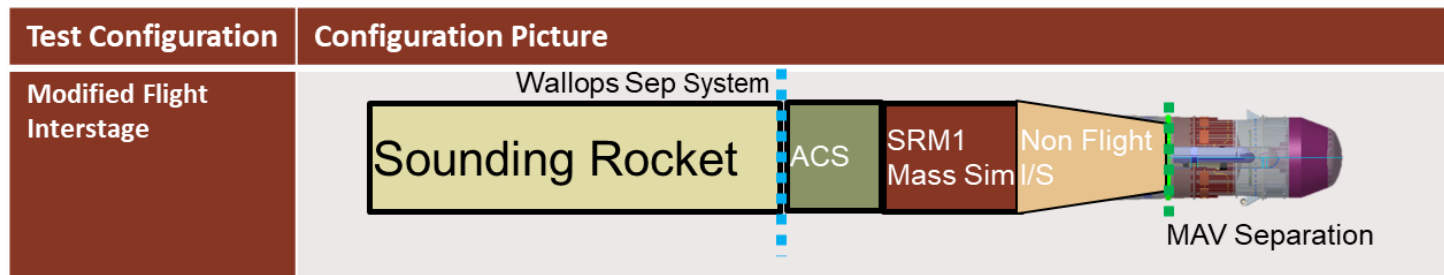


Mars Ascent System (MAS)

Two stage solid Rocket Motor MAV (SSGU)
 Integrates to the VECTOR, launch system
 Enveloped by a thermal enclosure
 Receives Sample tubes in the OS
 Launches OS into required orbit
 Release OS into stable orbit for rendezvous and capture by ERO

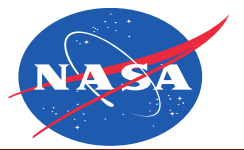
*Conceptual elements shown. Not to scale.

- Second stage only flight test being planned at Wallops Flight Facility
 - Launch second stage of the MAS from a sounding rocket
 - The current plan is for two flight tests with a contingency for a third in the event that any of the tests are unsuccessful (objectives not met insufficient data, SR failure, etc.)
- Flight test solution addresses required Flight Test Objectives (FTO's):
 - FTO#1 Reduce SRM2 flight knockdown factor uncertainty – bound the difference in performance of the second stage solid rocket motor from ground testing to flight
 - FTO#2 Characterize second stage integrated dynamics
 - FTO#3 Demonstrate that the separation system performs its functions



- MSR is currently in Phase A
 - Planning is in place for all elements of the mission
 - Perseverance has begun collecting samples
- MAS is part of a much more complex flight system, designed to deliver those samples to orbit around Mars for potential return to Earth. Launch as early as the late 2020's.
 - This would be the first rocket launch from another planet
- MAS is a collaboration between JPL, MSFC and industry partners
 - Significant progress has been made on the MAV design
 - Flight test planning in progress for second stage
 - Northrop Grumman on contract to deliver solid rocket motors, testing to start as early as next year
- VECTOR testing to begin at JPL this week with a mass model

Questions?

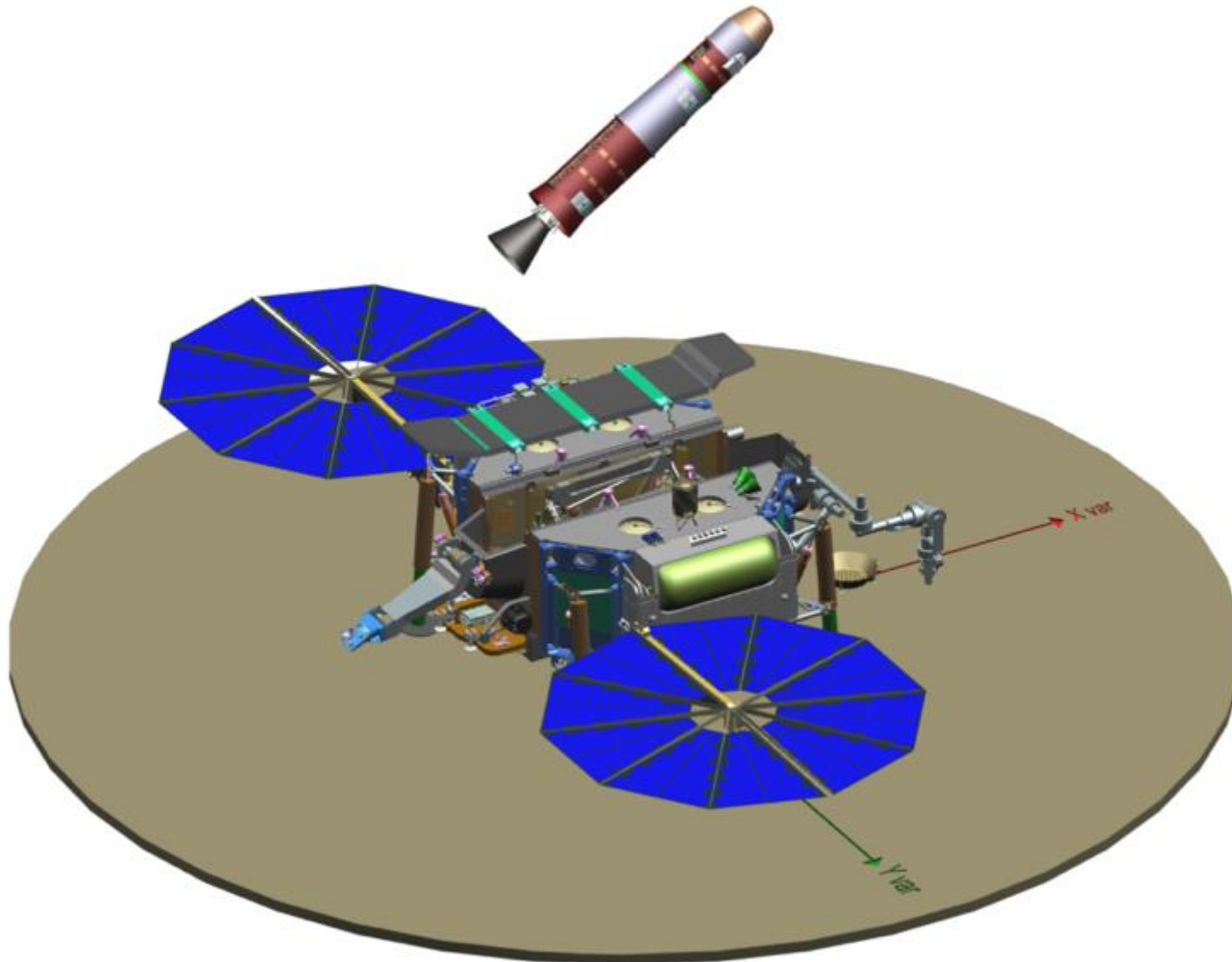


Mars Sample Return Program

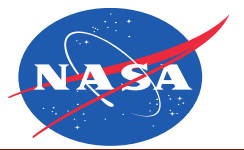


Artist's concept

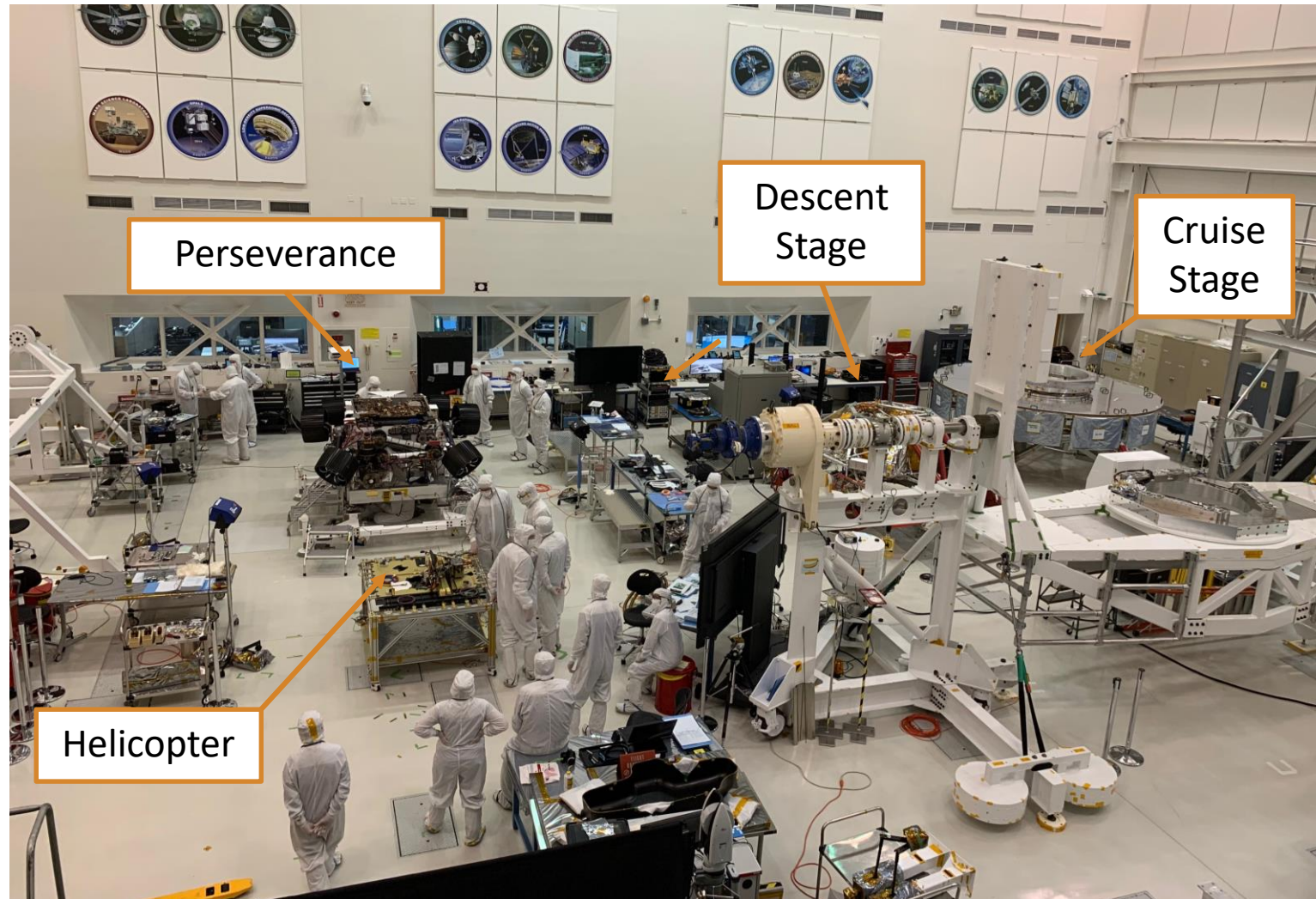
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Mars 2020 in ATLO

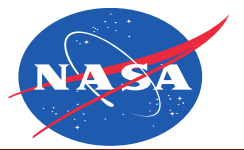


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Hybrid Rocket Technology Development



Mars Sample Return Program

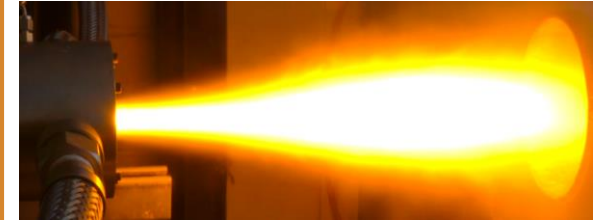
New Propellant Combination



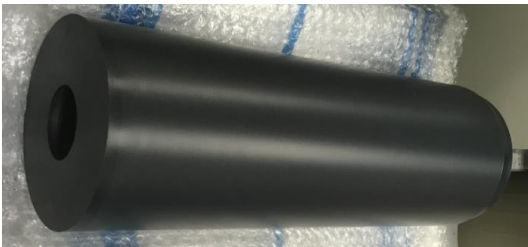
Motor Testing



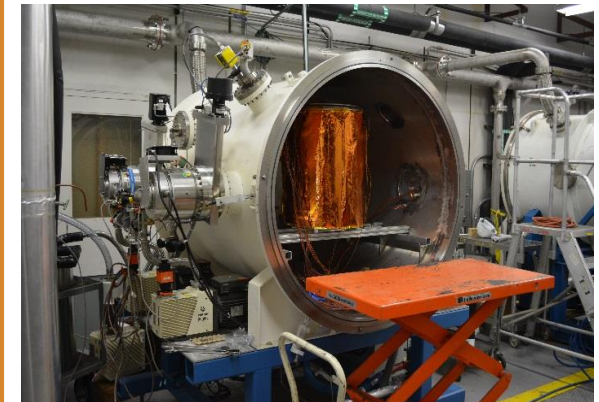
Hypergolic Ignition



Grain Manufacture



Thermal Cycling





WHITTINGHILL
AEROSPACE

Flight –Type 01 Firing

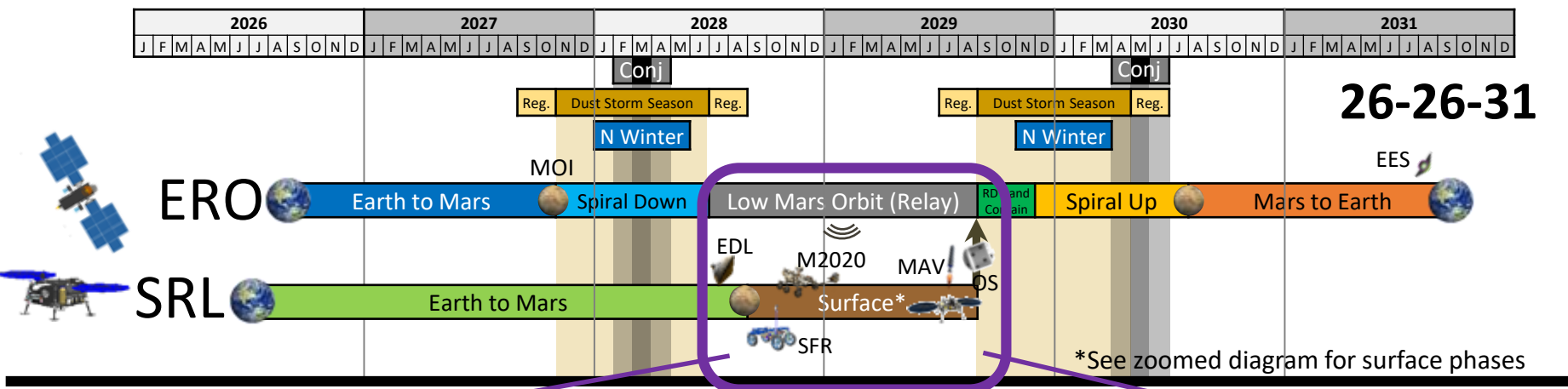
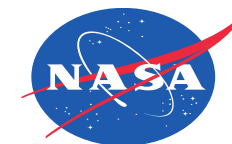
90 second total duration

Two burns:

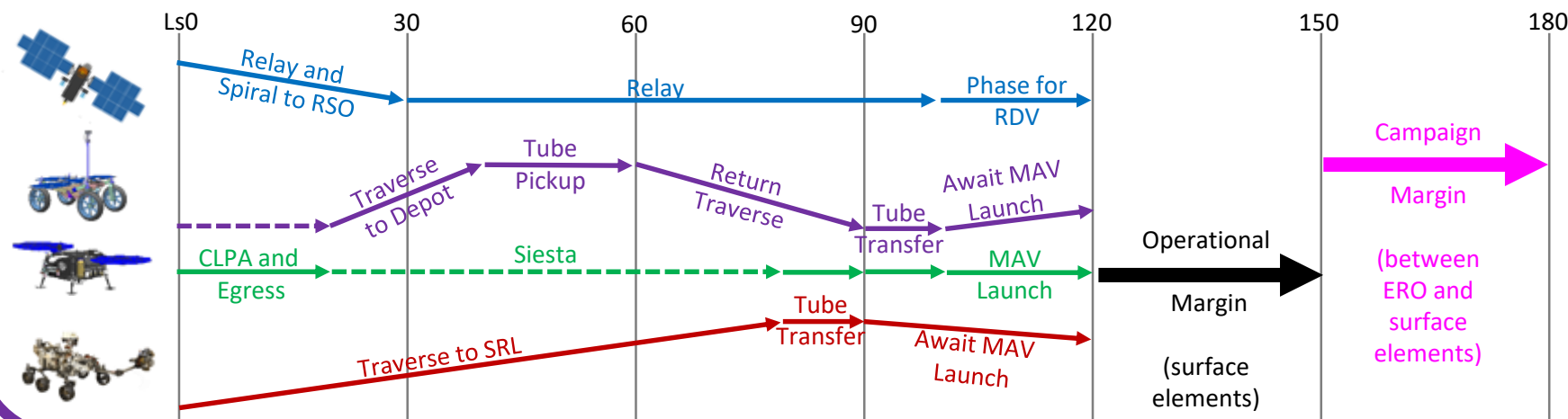
85s boost / 5s insertion

Automated restart

Campaign Timeline Example*



SRL Surface Activities (~13 months) is a busy time and campaign coordination is critical



*Different potential launch dates are under consideration and this is given for example only